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Ultra-High Temperature Ceramics: Materials for Extreme Environment Applications IV

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Novel Ir-X thermal protection coatings designed for extreme aerodynamic heating environment

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Novel Ir-X Thermal Protection Coatings Designed for Aerospace Heating Environment

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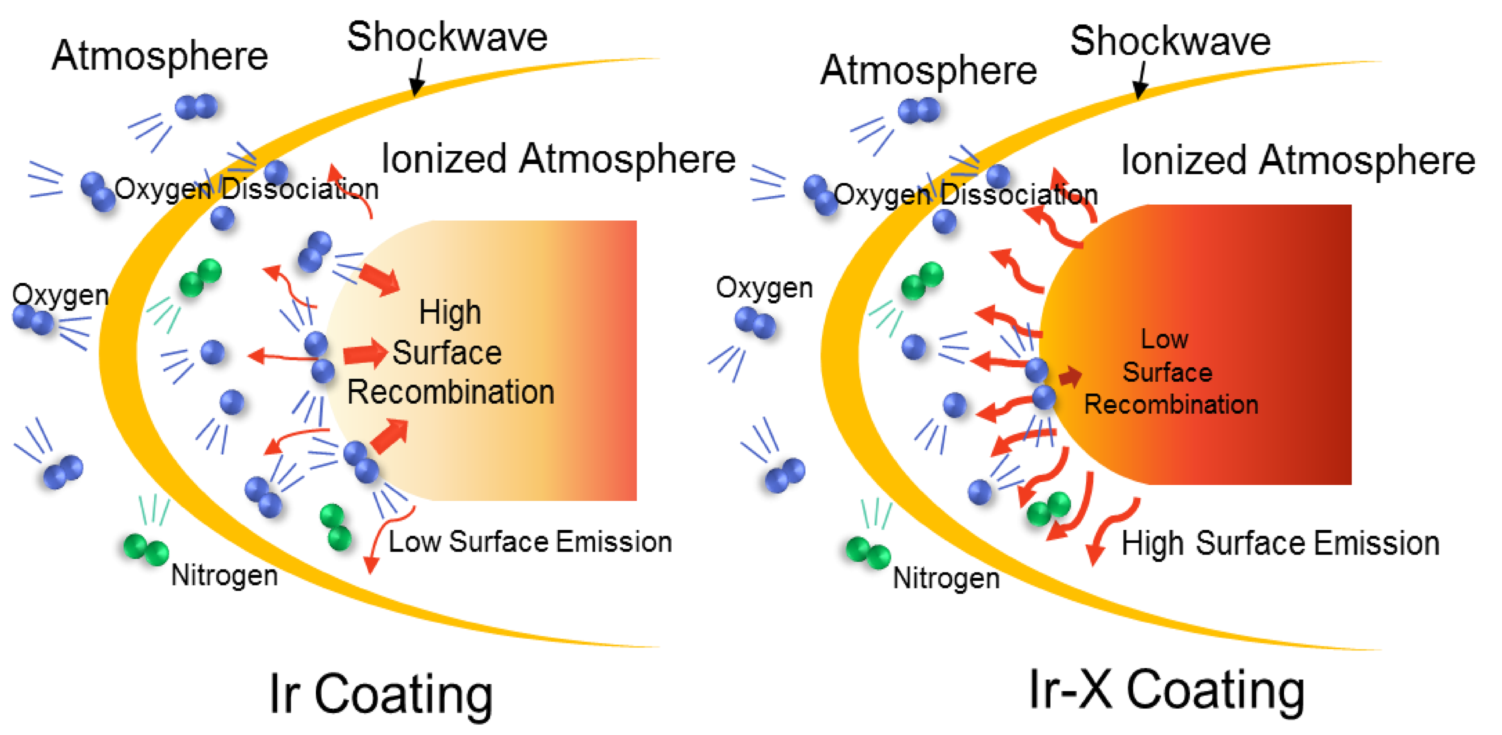
Abstract

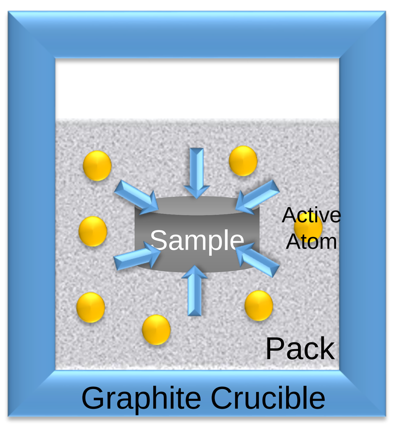
Though being promising in ultra-high temperature application, Iridium coating exhibit low emissivity(ε) and high catalycity(γ) in dissociative atmosphere, which lead to additional heat for hypersonic application. By adding alloy elements X (Al, Cr, Zr…) through pack cementation, Ir-X diffusion coatings were prepared to improve the above properties. Microstructure, element distribution of Ir-X coating were characterized and ε and γ of the coatings were measured. The results showed that Ir-X coatings had a much lower catalycity and higher emissivity, and meanwhile decreased surface temperature in dissociative environment.

Graphic Abstract



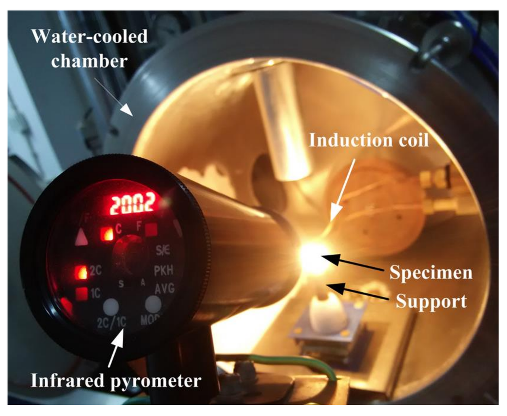
Experiment & Characterization

- **Pack Cementation Pre-Oxidation**



- ☐ Element: X=Al, Cr, Zr, Y, Ta
- ☐ Pack component: X+XO+NH_4Cl/XCl.
- ☐ Temperature: 800℃-1600℃

- **Pre-Oxidation**

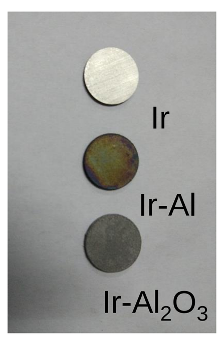


- ☐ Aim: Oxide Scale Formation
- ☐ Induction heating
- ☐ Infrared thermometry
- ☐ 1200℃/30min 1atm

- **Microstructure Characterization**

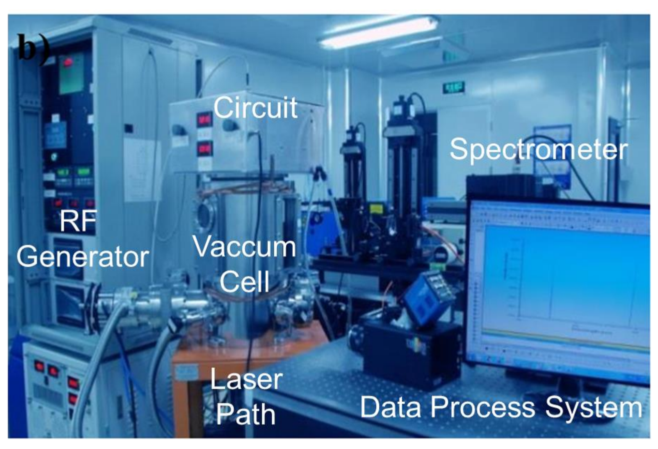
☐ SEM ☐ XRD ☐ EDS

- **Emissivity Measurement**



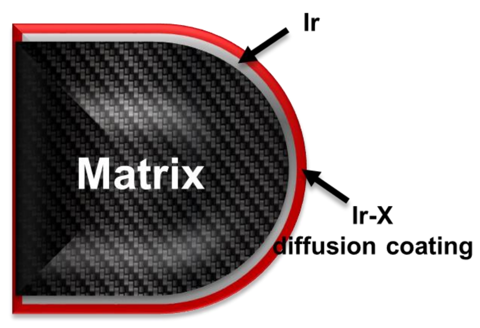
- ☐ Bruker Vertex70 FTIR
- ☐ Wavelenth: 400-4000nm
- ☐ Sample: Ir Ir-X Ir-XO

- **Surface Recombination Test**

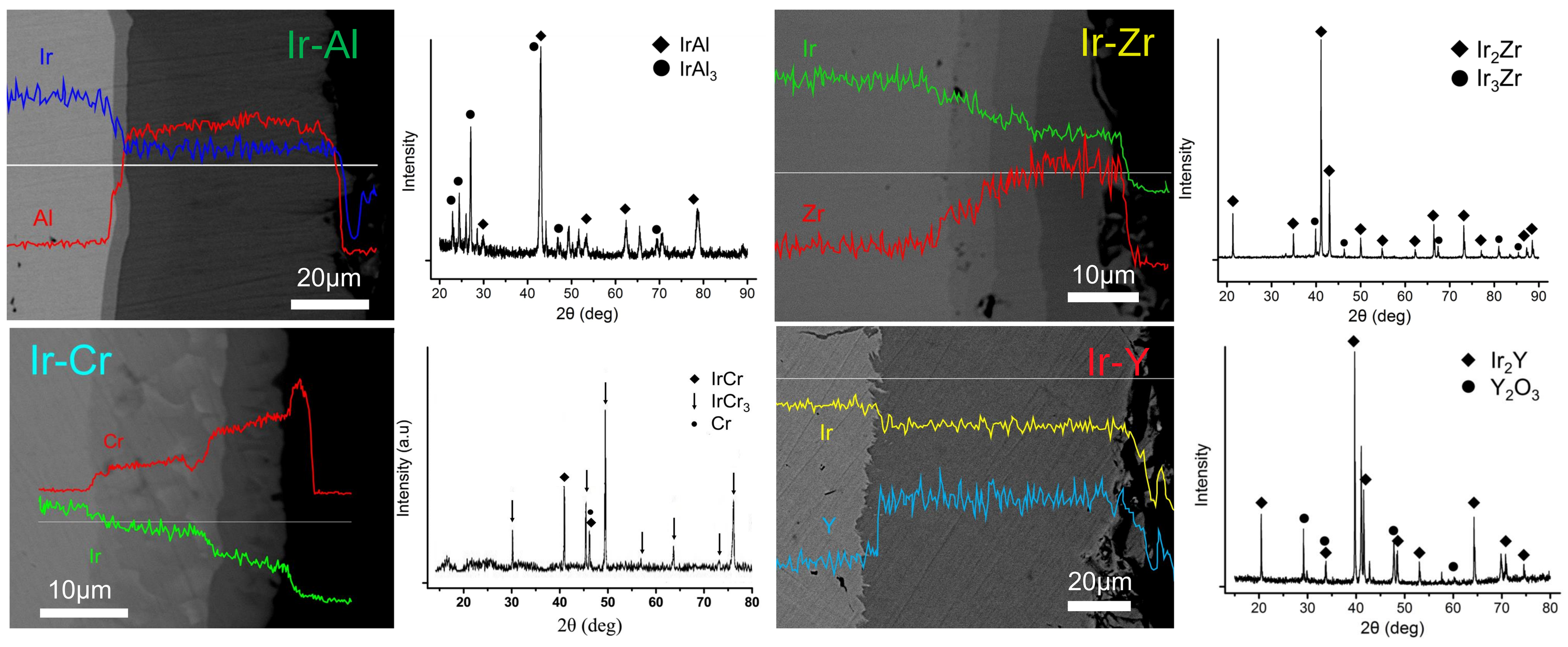


- ☐ RF Generator for O_{atom}
- ☐ Laser Sample Heating
- ☐ MESOX Method for γ
- ☐ Double colorimeter for T

Results & Discussion

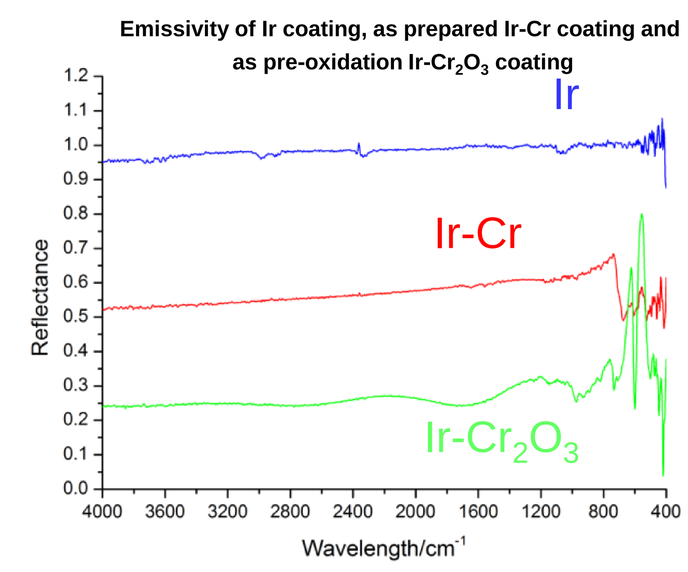


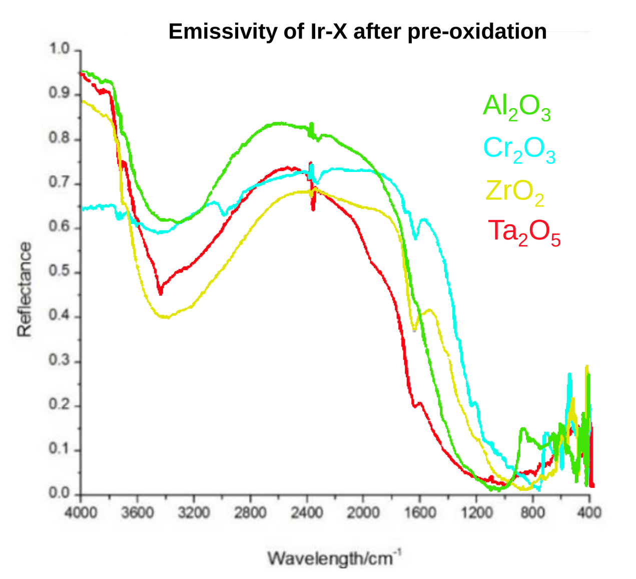
- **Coating Microstructure**



Several Ir-X diffusion coatings were prepared through pack cementation

- **Coating Emissivity**

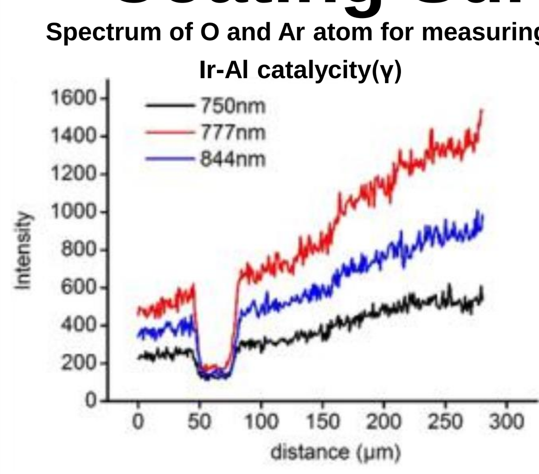




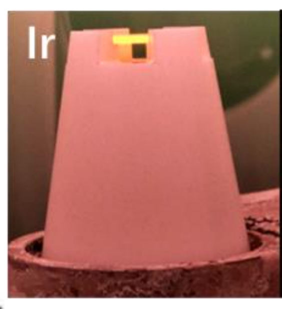
Coating	Emissivity(ε)
Ir	0.017
IrCr	0.433
IrAl	0.465
Cr_2O_3	0.723
Al_2O_3	0.759
ZrO_2	0.547
Ta_2O_5	0.57

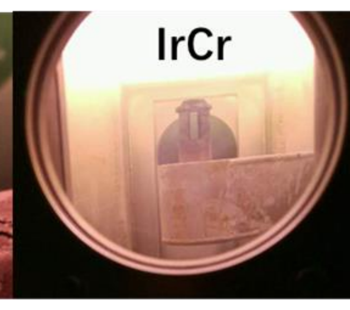
※ Measured at Room Temperature

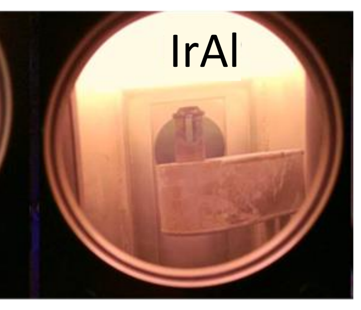
- **Coating Surface Recombination**



Phenomenon and surface temperature of Ir, IrCr and IrZr in dissociative O_2/Ar without heating







T=1150C° T=390C° T=370C°

Coating	Catalycity(ε)
Ir	0.65
Ir	0.7
IrAl	0.004(RT)
IrAl	0.47(1400℃)
Ir-Al_2O_3	0.009(RT)
Ir-Al_2O_3	0.55(RT)

$$\gamma = \left\langle \frac{\frac{I_O}{I_{Ar}}\Big|_{x=L}}{\frac{I_O}{I_{Ar}}\Big|_{x=0}} \cdot \frac{T_s}{T_L} - L \right\rangle \frac{4D_0}{V^{*}L}$$

Temperature of Ir and Ir-X coating in dissociative O_2/Ar without heating ※ Measured at 20Pa

Coating	Ir	Ir-Al	Ir-Cr	Ir-Zr	Ir-Ta	Ir-Y
Surface T(℃)	1150	370	390	345	424	369

Conclusions

- ☐ Ir-X(X=Al, Cr, Zr, Y, Ta) intermetallic coatings with compact single or multilayer scale could be prepared through pack cementation.
- ☐ After cementation, Ir-X diffusion coating could largely increase emissivity and decrease catalycity, resulting in a lower surface temperature at dissociative atmosphere.

Acknowledgments

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